



Valérie RENAUDIN

Dr. Valérie Renaudin is a Professor at IFSTTAR (the French Institute of Science and Technology devoted to Transport, Planning and Networks). She received the M.Sc. degree in geomatics engineering in 1999, and the Ph.D. degree in computer, communication, and information sciences from the EPFL in 2009. She was a Technical Director at Swissat Company, Switzerland, developing real-time geopositioning solutions based on a permanent GNSS network, and a Senior Research Associate with the PLAN Group, University of Calgary, Canada. She is currently leading the Geopositioning Laboratory (GEOLOC) at IFSTTAR, France where she built a team specializing on positioning and navigation for travelers in multimodal transport. Her research interests include outdoor/indoor navigation using GNSS and inertial and magnetic data, particularly for pedestrians to improve sustainable personal mobility. She is a member of several editorial boards and of the steering committee of the international conference on "Indoor Positioning and Indoor Navigation".



第十届中国卫星导航年会

THE 10th CHINA SATELLITE NAVIGATION CONFERENCE

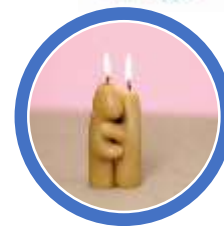
Indoor positioning: towards an infinite number of technologies?

Prof. Valérie RENAUDIN
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IFSTTAR / Gustave Eiffel University

导航, 遇见十年
NAVIGATION, 10 YEARS AND BEYOND

CSNC 2019 10周年 2010-2019

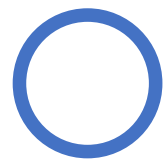
Some popular indoor technologies on the market



Light Fidelity



Motion Detection



Facial Recognition

Smartphone

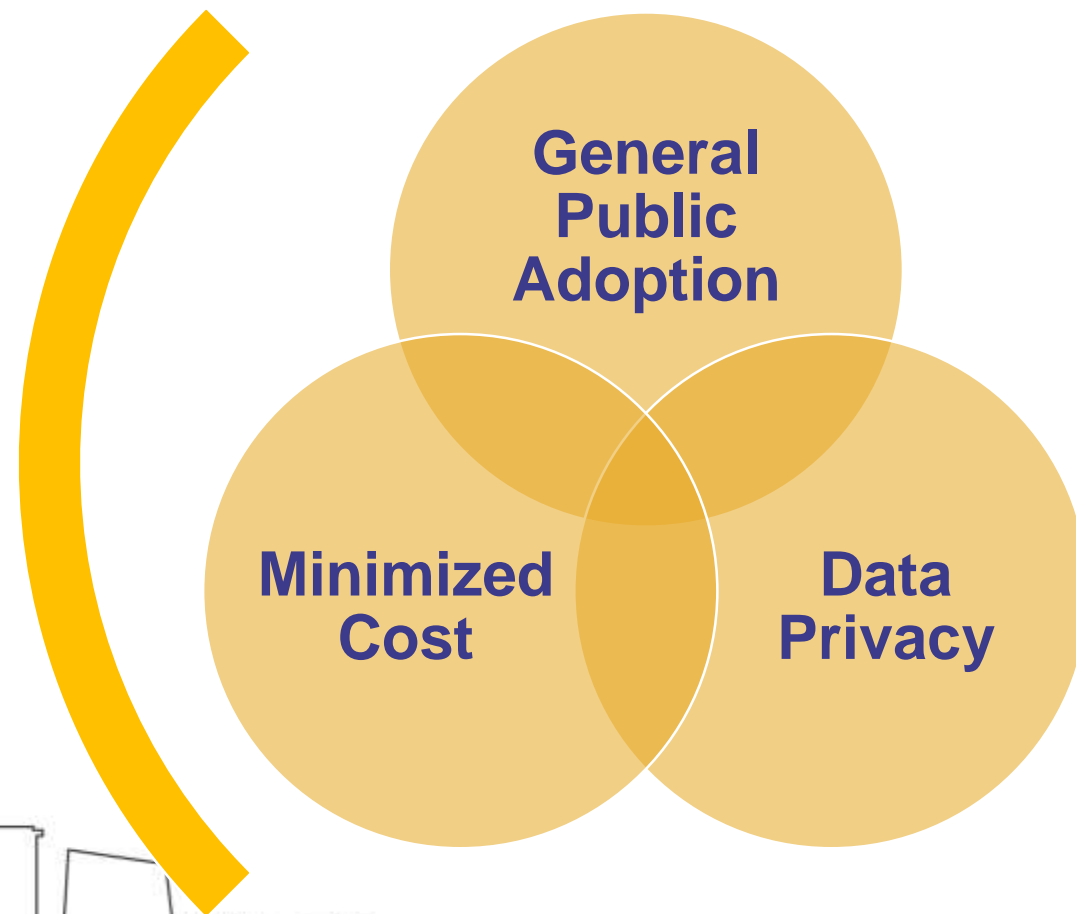


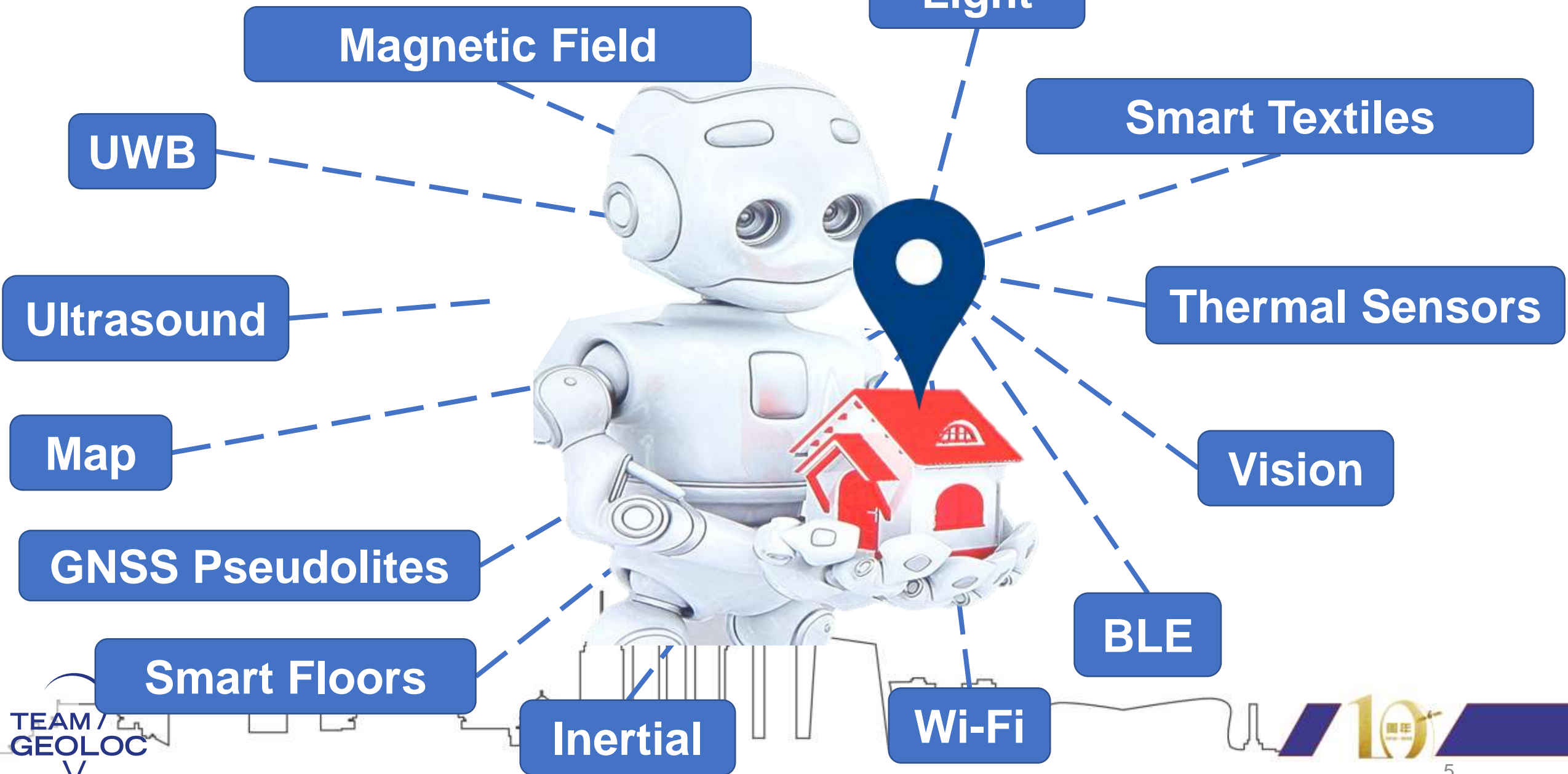
Vocal Assistant

Application Fields



Social Context





Two categories of indoor positioning technologies



Indoor
infrastructure
equipment

Self-contained
technique

Indoor infrastructure equipment

Radio-propagation
(WiFi, UWB, BLE, RFID)

Magnetic prints

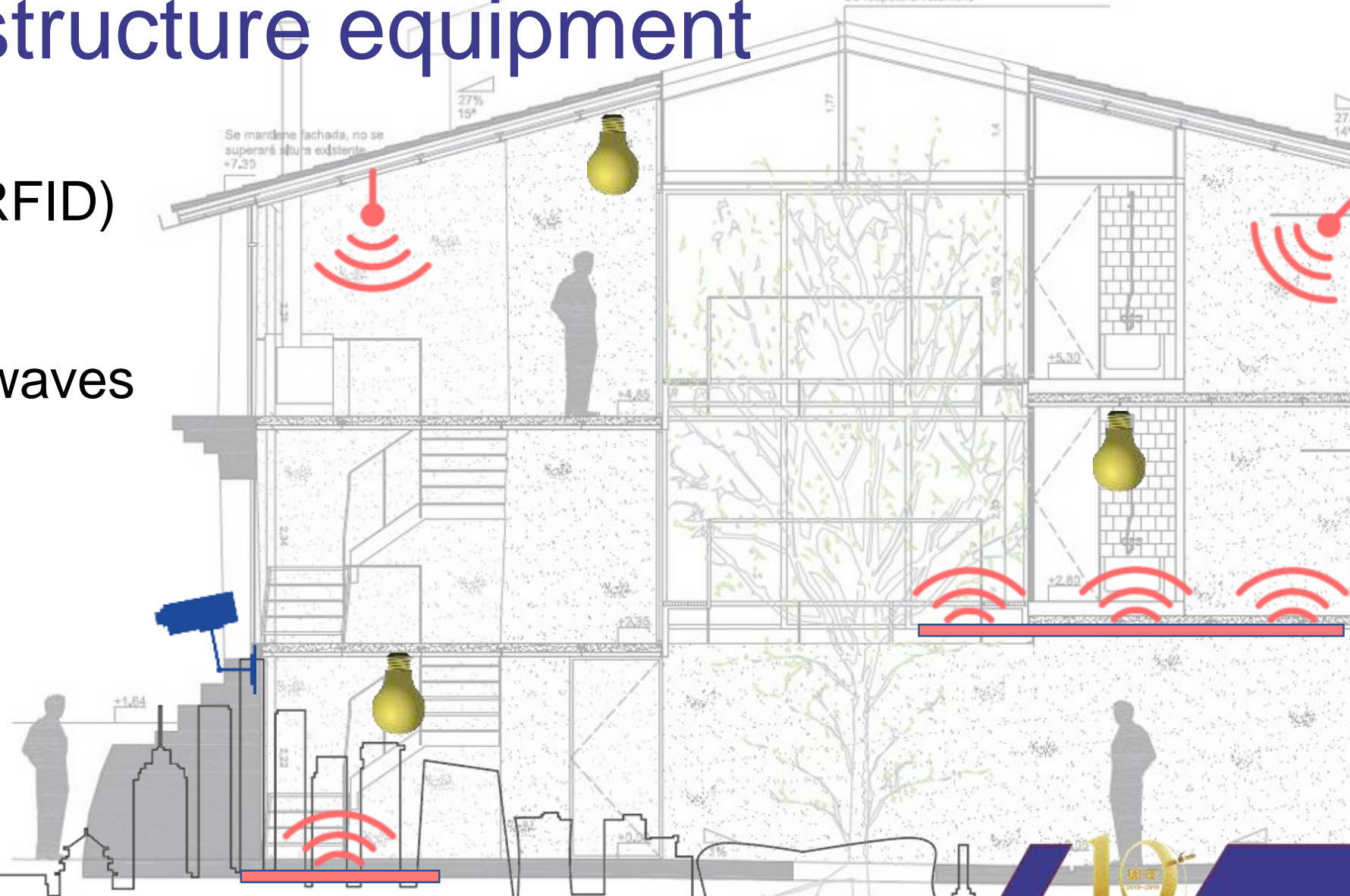
Ultrasound, sound waves

Vision, camera

Light

Thermal sensors

Smart floors



Self-contained technique

Vision (VO, AR)

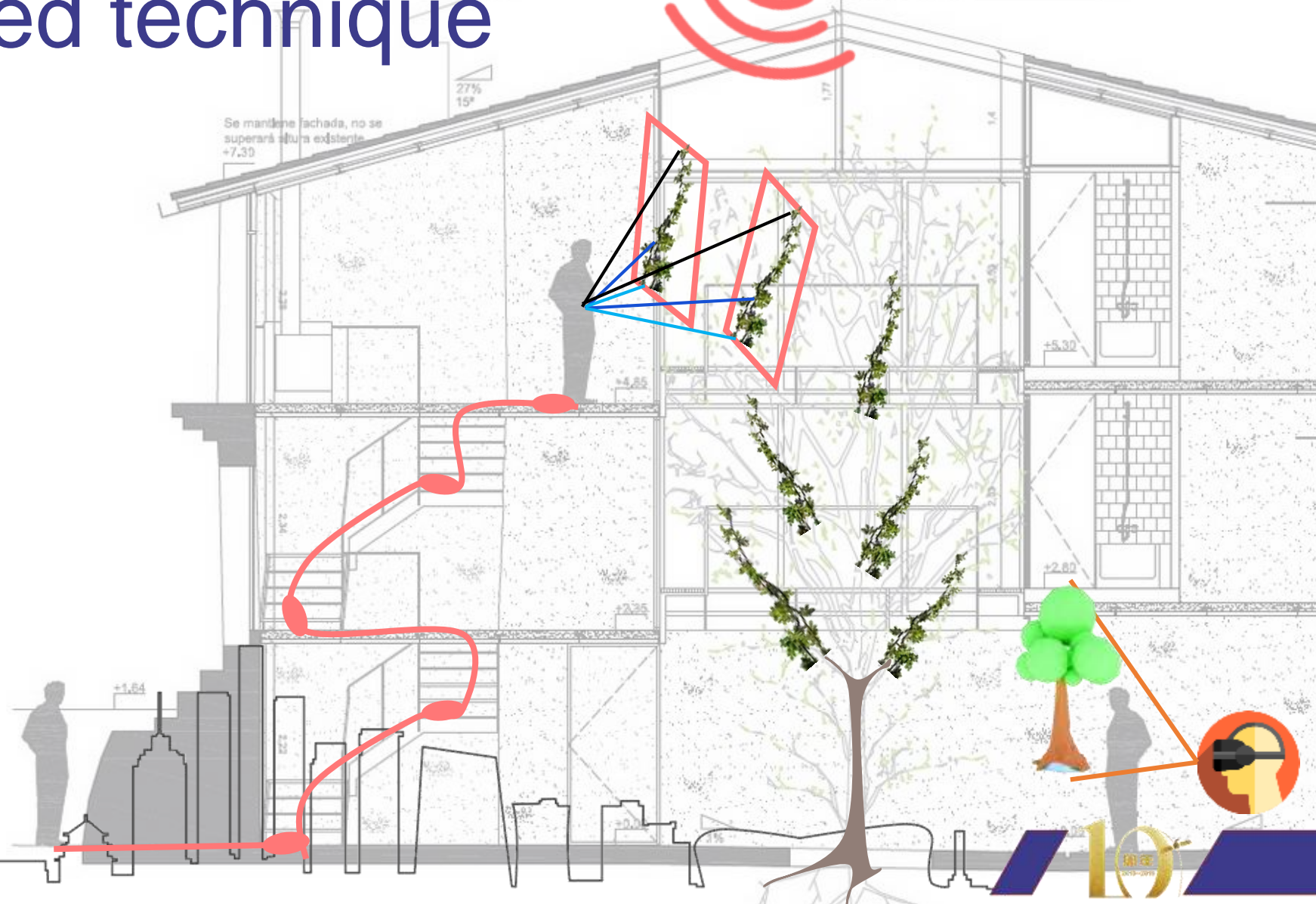
Inertial sensors

Magnetic field

GNSS

Smart textiles

NB IOT - 5G



Sensor fusion is the key!

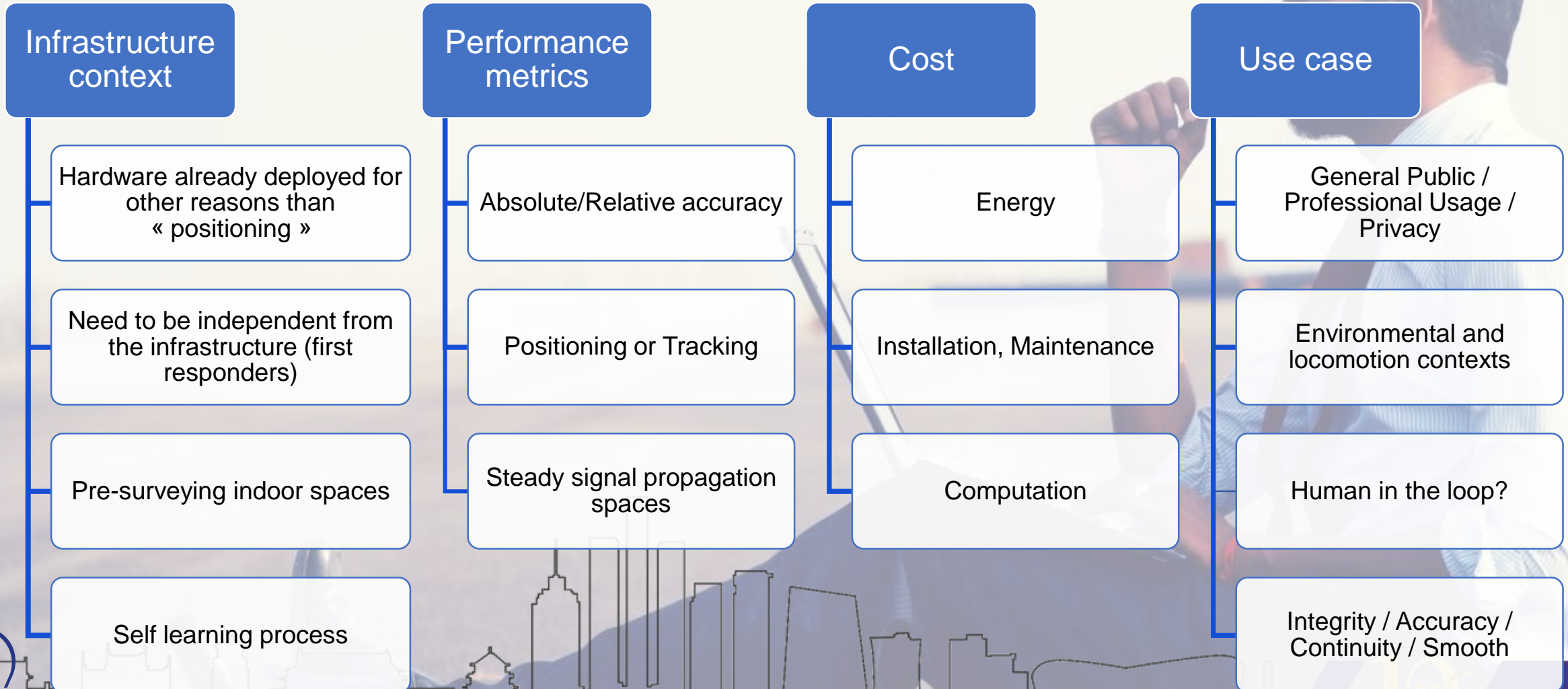
Despite decades of research, no universal solution has been adopted indoors

Seamless, ubiquitous and accurate positioning means sensor fusion

Difficulties to integrate all technologies

How to choose?

A question of criteria?



Main sensor fusion strategies

Linear Quadratic Estimation

- Kalman Filters, ...
- Minimization of the quadratic error
- Suitable for real time processing approach
- Mature and easy to implement
- Not suitable for integrating spatial constraints

Sequential Monte Carlo

- Particle Filter, ...
- Non-linear state-space modelling by particles clouds corresponding to distribution
- Easy integration of spatial and movement constraints
- Significant computation costs

Learning Methods

- Neural network, Decision tree, Clustering, Dimension reduction, LSTM, ...
- Native approaches to classify / recognize context
- Require large amounts of data
- How to control data quality? Supervised/Unsupervised?

Evaluation of indoor positioning systems

GOAL

Establish reference points & performance metrics to compare positioning solutions

Evaal EU project
www.universaal.org
2011-2014

Associated to IPIN int. conference
2015 - 2019



- Normalization
 - International Standard ISO/IEC 18305:2016 : scenarios and metrics definition
 - NIST: National Institute of Standards and Technology (PerfLoc)
- Some other international competitions



NIST



Atlantis shopping mall - Real life space

4 Tracks / 34 Teams

- 1) Camera based Positioning (on-site)
- 2) Non Camera based Positioning (on-site)
- 3) Smartphone based Positioning (off-site)
- 4) Foot-Mounted IMU based Positioning (off-site)

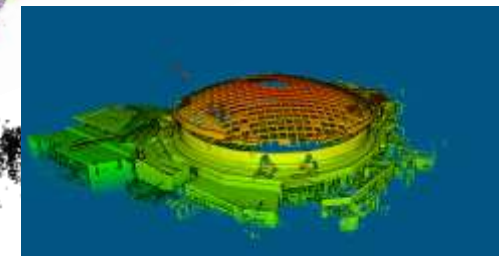
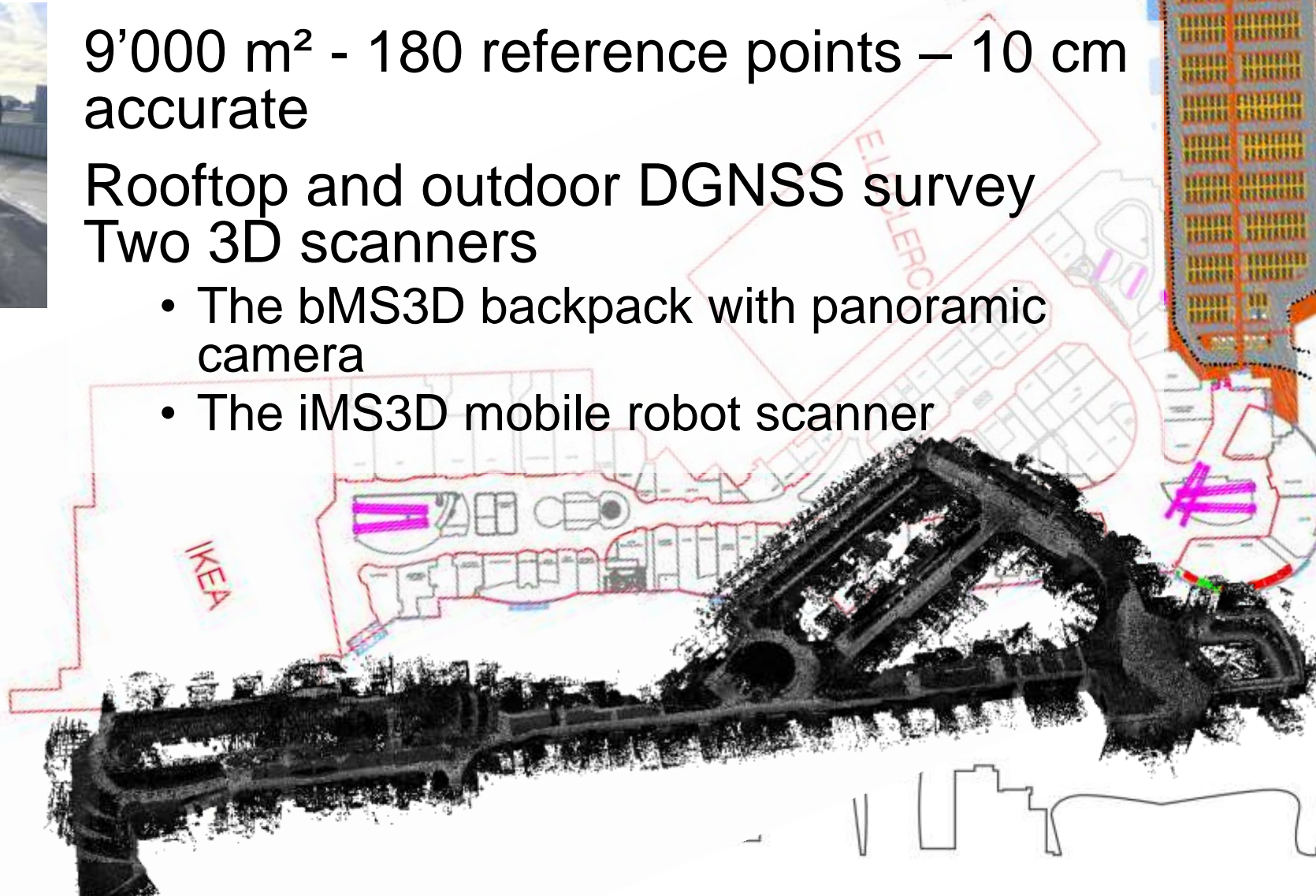
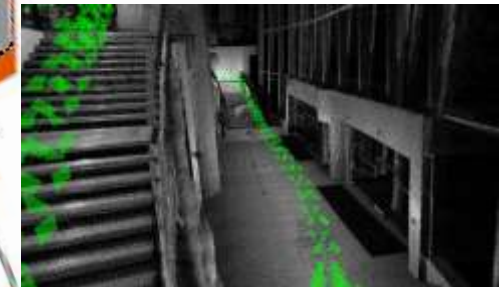


Mobile Mapping of the Mall

9'000 m² - 180 reference points – 10 cm accurate

Rooftop and outdoor DGNSS survey
Two 3D scanners

- The bMS3D backpack with panoramic camera
- The iMS3D mobile robot scanner



Track 1: camera based positioning



Track Challenges

5 teams
870 m indoor only with travellers and parking
3 breaks of 15 sec and 3 floors



Technologies

Visible light, Augmented & Mix Reality (ARCore, ARKit), Inertial Sensors, Segmented Map and Images



Processing

Pre-surveying by SLAM, Particle Filter (segmented map & images), Hybridization (PDR, Optical Flow)

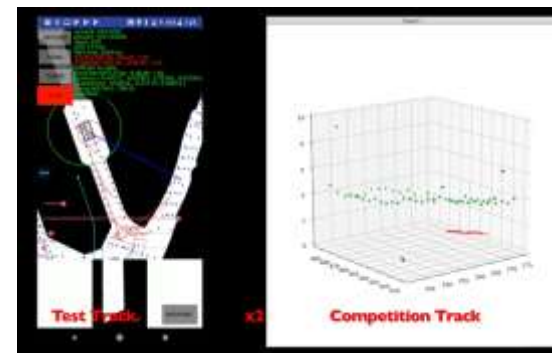


Results

Top 3 - 75% CDF - 15m penalty on floor error
ARIEL-2 : 11.7 m
ARIEL-1: 15.2 m
ETRI: 18.9 m



Team ARIEL-2 ©



Team ARIEL-1 ©



Team ETRI ©

Track 2: non camera based positioning



Track Challenges

10 teams
840 m indoor and outdoor with stairs, travellers and parking
2 breaks of 15sec and 3 floors



Technologies

Inertial sensors, Barometers, Indoor Map



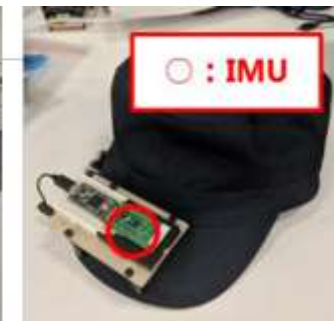
Processing

Highly accurate sensor calibration (incl. Temperature), PDR, Particle Filter for floor matching, Deep Neural Network learning for step length estimation



Results

Top 3 - 75% CDF - 15m penalty on floor error
SONY: 5.5 m
KYUSHU: 5.7 m
ETRI: 16.8 m



Team SONY©



Team KYUSHU



Team NESL-ETRI©

Track 3: smartphone based positioning (offsite)

Track Challenges



15 teams
1 km - indoor only – 1 loop -1 lift and 1 traveller
2 breaks of 15sec, 3 floors

Technologies



INS, Barometer, Magnetometer, WiFi, GNSS, Barometer, BT

Processing

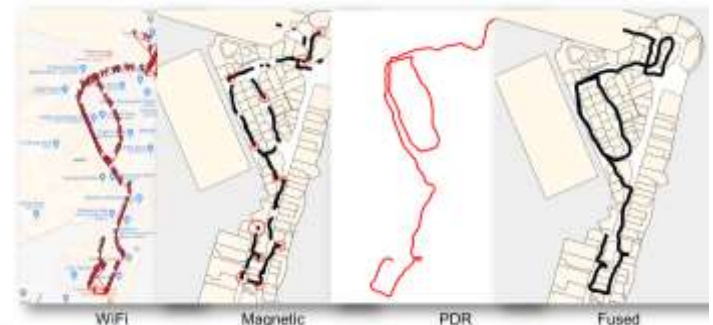
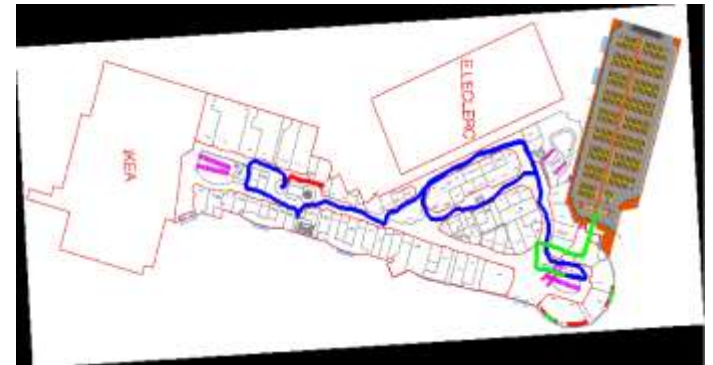


Strapdown Mechanization, PDR, UKF, Neural Network, Map Matching, Fingerprinting (WiFi, Mag)



Results

Top 3 - 75% CDF - 15m penalty on floor error
Five-WHU: 1.1 m
EGEC: 1.5 m
TENCENT: 2.5m



Team Five-WHU©

Team EGEC©

Team TENCENT©

Track 4: Foot-Mounted IMU based Positioning (off-site)

Track Challenges



4 teams
1 km indoor outdoor with stairs, traveller and parking
2 breaks of 15sec and 3 floors

Technologies



IMU (6 DoF), Magnetometer, GNSS

Processing



IMU Calibration, Strapdown inertial navigation, Complementary Filter, Stochastic Cloning KF, Machine learning based on mobility pattern, Generalized Likelihood Ratio Test



Results

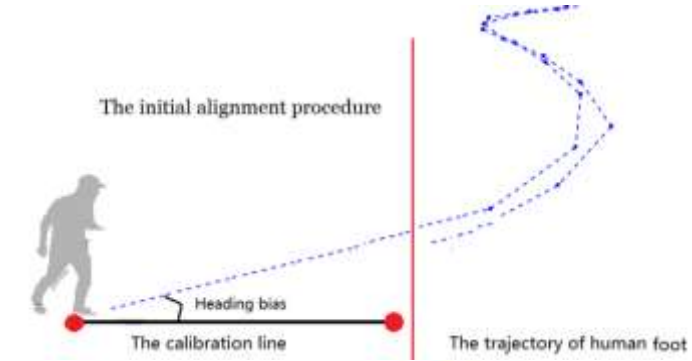
Top 3 - 75% CDF - 15m penalty on floor error
WHU: 1.3 m
KIT: 3.9 m
AOE.AC.CN: 7.9 m



Team WHU©



Team KIT©



Team AOEACCN©

To summarize

- Reasons for diversity
 - The use cases features drive the development of novel technologies
 - Challenges of indoor positioning are addressed by numerous scientific domains (navigation, computer science, robotic, data mining, biomechanics, ...)
 - The impact of inter and intra individual differences on positioning performance is often underestimated
- A question of sensors or a question of human needs?
- Most probably no limit to the development of novel and hybridized solutions

谢谢观赏

THANK YOU